MARS METHANE ANALOGUE MISSION (M3): NEAR SUBSURFACE ELECTROMAGNETIC TECHNIQUES AND ANALYSIS. A. Boivin[1], C. Samson[1], J. S. Holladay[2], E. Cloutis[3], R.E. Ernst[1,4] [1]Dept. of Earth Sciences, Carleton University, Ottawa, ON, Canada K1S 5B6; aboivin@connect.carleton.ca, [2]Geosensors Inc., 66 Mann Ave., Toronto, ON, Canada M4S 2Y3; [3]Dept. of Geography, 515 Portage Ave., University of Winnipeg, Winnipeg, MB, Canada R3B 2E9; [4]Ernst Geosciences, 43 Margrave Ave., Ottawa, ON, Canada K1T 3Y2.

Introduction: Funded by the Canadian Space Agency (CSA) through its Analogue Missions program, the Mars Methane Analogue Mission is a micro-rover mission whose goal is to detect, analyze, and determine the source of methane emissions in an setting simulating as closely as possible the Martian geological environment [1-2]. A preliminary deployment using a test rover was conducted in June 2011 in Jeffrey Mine, an asbestos mine located in the Appalachian hills of the province of Quebec, Canada. A second, more complex rover deployment is planned for summer 2012.

During the June 2011 deployment, the test rover was equipped with a video camera for navigation purposes. Although not mounted on the rover at this stage, a suite of instruments were utilized [2], including a geophysical field instrument, an Electromagnetic Induction Sounder (EMIS) (Figure 1). This was done with the goal of demonstrating the value of the EMIS as a potential science instrument onboard future rovers. The capabilities of the EMIS were demonstrated by: (1) Measuring the electrical conductivity and magnetic susceptibility of several geological units; (2) Determining the locations of major geological contacts.

Along with the in-situ EMIS measurements, laboratory magnetic susceptibility measurements were made on samples returned from the mine and compared to the EMIS field results.

Geology of the Jeffrey Mine: The Jeffrey Mine is the largest open pit asbestos mine outside of Russia. It is approximately 700 m deep and 3 km × 1 km wide. The mine is cut across by a major regional fault [3] and the two main rock types are peridotite (serpentinite bearing) and slate, separated by a shear zone which has been heavily metamorphosed and characterised by the presence of schist. The peridotite-shear zone-slate contacts are the expression of this fault in the mine [1]. The EMIS was deployed on three different levels in the mine, one of these being the level of the micro-rover deployment (Figure 2). In the two levels above the level of rover deployment, the EMIS traverses cross a fold, causing a second manifestation of the shear zone unit [4]. Samples were taken from each of the peridotite, shear zone, and slate units as well as from the gravel road on the level of rover deployment.

The Electromagnetic Induction Sounder:

The EMIS is a geophysical instrument which emits a time-varying “primary” electromagnetic field from a transmitter. Eddy currents are then induced in subsurface conductors, according to Faraday’s Law, which generate a “secondary” electromagnetic field. The primary and secondary fields are sensed by a receiver [5-6]. The instrument used was the Dualem-2 produced by Geosensors Inc. of Toronto, Ontario. The Dualem-2 comprises a cylinder containing one transmitter loop oriented in a plane parallel to the ground surface (Z-direction) and two receiver loops, one also oriented in the Z-direction and one oriented vertically (X-direction), plus electronics and an external user interface. The secondary fields are separated by the internal processor into components inphase and in quadrature with the primary field. The transmitter and the receivers are separated by a distance of 2 m and operate at 9 kHz. The data recorded by the receiver oriented in the x-direction probes the subsurface to a depth of approximately 1.2 m, while the data recorded by the receiver oriented in the z-direction investigates to a depth of approximately 3 m [7]. The instrument has been designed to operate at low induction number, therefore the quadrature signal recorded is proportional to apparent conductivity, while the inphase signal is proportional to magnetic susceptibility in MKS units [8]. This greatly simplifies data processing.

Serpentine has an expected resistivity range of 2×10^2 Ωm – 3×10^3 Ωm, slate an expected range of 6×10^2 Ωm – 4×10^7 Ωm, and schists an expected range of 10 Ωm – 10^4 Ωm [9]. Due to the strong conductivity contract between these units, we expected the EMIS to be able to adequately characterise the different rock types in the mine and their contacts.

Electromagnetic survey: During the June 2011 deployment, two EMIS survey types were conducted: horizontal surveys and vertical soundings. Both survey types yield measurements of electrical conductivity and magnetic susceptibility. Horizontal surveys are conducted with the EMIS mounted on a non-conductive sled such that the height of the instrument is 0.25 m above ground level (Figure 1). In this survey type, the EMIS sled was dragged along a traverse and data was automatically taken at 1 second intervals. Horizontal surveys were conducted multiple times on each of the traverse levels, leading very consistent data (Figure 3).

Vertical soundings consist of taking measurements at different instrument heights at a given location. This allows us to characterize the conductivity and magnetic susceptibility gradient, and also helps to further constrain any models derived from the data. A total of 7 vertical soundings were conducted at the level of rover deployment with two soundings each in the peridotite and slate units, and 3 soundings in the shear zone. Heights used for the soundings were 0.25 m, 0.5 m, 1.0 m, and 1.6 m above ground level.

Results: Apparent conductivity profiles in the horizontal coplanar (ZZ) orientation for the horizontal surveys show clear boundaries between the different geological units in the mine (Figure 3). As expected the slate was much more resistive than the shear zone, although it is worth noting that it was less resistive than predicted by [9]. This is possibly due to a high degree of water saturation in the mine. The shear zone was highly variable but relatively conductive on average. Low conductivity regions in the shear zone are interpreted to be granitic dykes.

In the laboratory, samples from both the peridotite and slate units yielded lower magnetic susceptibilities than measured by the EMIS, however both units were much lower in susceptibility than the shear zone, which was relatively high on average in both the sample and EMIS results. The shear zone was also very variable in both results which indicates that susceptibility trends seen with the EMIS are also present in the samples (Figure 4).

Conclusion: The EMIS is a rugged instrument that is well suited to field use in an analogue mission setting. It has no moving parts and can be controlled from a simple to use hand-held device. It produces stable results which are easy to interpret and minimal processing is required. Simply plotting instrument output against distance clearly shows the locations of geological contacts between units with differing conductivity and/or magnetic susceptibility. Were the EMIS to be mounted on a rover, electromagnetic interference would be an issue which would require careful attention.

References: [1] Boivin A. et al. (2011) LPS XXXXII abstract #1472. [2] Cloutis E. et al. (2011) LPS XXXXII abstract #1174. [3] Turcotte P.L. et al. (1989) Géog. Phy. et Quat., 43, 131-146. [4] Tremblay A. (2011) pers. comm. [5] Samson C. et al. (2006) CASI ASTRO 2006, Paper 17. [6] Grant F.S. and West G.F. (1965) Interpretation Theory in Applied Geophysics. [7] Manual for DUALEM (2002), Dualem Inc. (*http://www.dualem.com/dman.htm*). [8] Callegary J.B. et al. (2007) Vadose Zone Journal, 6, 158-167 [9] Telford W.M. et al. (1990) Applied Geophysics, 2nd Ed.

Acknowledgments: We wish to thank Mr. Claude Lortie of Mine Jeffery Inc. for hosting the team at the mine and the CSA for their generous support.

Figure 1. EMIS data being recorded 10 m behind the test rover during June 2011 deployment.

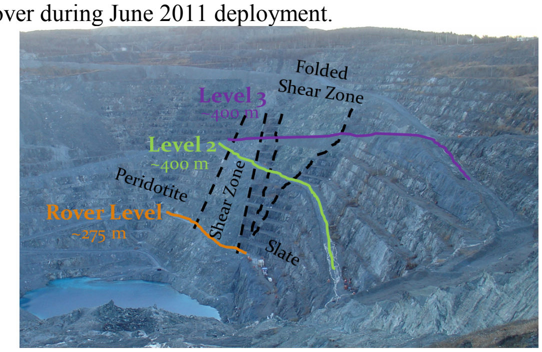

Figure 2. Traverses and geological contacts in Jeffrey Mine in June 2011.

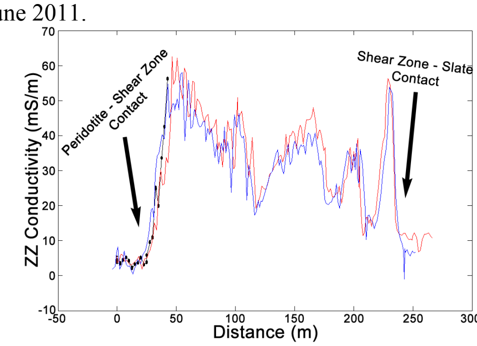

Figure 3. Conductivity in the ZZ direction from 3 traverses at the level of rover deployment. The data taken behind the rover (black squares) are discrete measurements taken at 5 m intervals. The data taken along the full length of the traverse (red and blue lines) were recorded continuously at 1 s intervals.

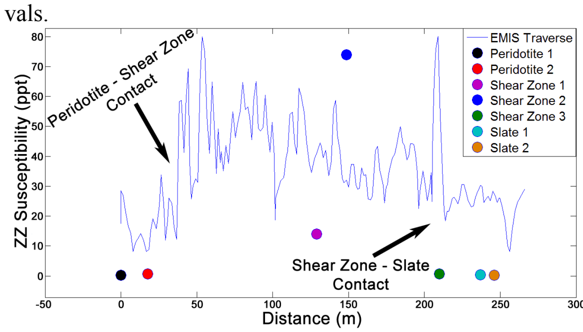

Figure 4. Magnetic susceptibility in the ZZ-direction (blue line) along a traverse at the rover level and measured on laboratory samples (coloured dots).